Facts about Ethanol

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Alcohol fuels have recen attracted attention l cause of their potential a petroleum fuel substitute. 1979, the Solar Energy Resear Institute (SERI) published "Fa About Gasohol," a brochu containing general informati about gasohol's producti potential and performance as motor fuel.

Since that time, much has changed on the alcohol fuels scene: As international oil price increases have slowed, sales of gasohol (10% anhydrous ethanol, and 90% unleaded gasoline) have crested and then dropped.

More attention is now being given to ethanol as a petroleum extender and octane enhancer rather than as a replacement for petroleum. Major gasoline producers are selling premium unleaded gasoline with 10% ethanol additions. This edition of "Facts About Ethanol" provides an update on alcohol fuels, covering these and other developments.

Alcohol Production

Alcohols are a group of organic compounds with the general formula $C_nH_{2n+1}OH$. One member of the group is *ethanol* (ethyl alcohol), obtained from the fermentation of sugars or starches. It is commonly known as grain alcohol. Ethanol is the alcohol most mentioned in the context of motor fuel use, and is the specific component that is blended with unleaded gasoline to produce gasohol.

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as a gasoline extender, because such blends are currently available throughout the United States.

Ethanol Production. Fermentation is a microbiological process in which microorganisms — such as yeasts — convert simple sugars to ethanol and carbon dioxide. Some plants are made of simple sugars, while others contain starch or cellulose that can be converted to sugars through cooking or enzymatic processes. In ethanol fermentation, a feedstock is reduced to a mash of simple sugar, to which yeasts are added in order to begin the microbiological process. The mash is kept warm to accelerate the biological action. This yields a beer, which must then be distilled to obtain fuel-grade ethanol.

Grains, sugar crops, potatoes and other starchy plants are commonly used for ethanol production. One bushel of corn (56 pounds) can yield 2.6 gallons of 200-proof (100%) anhydrous ethanol under well-managed conditions. (Potential yields from other feedstocks are shown in the chart.) In addition, 17 pounds of distiller's dried grains (DDG) and solubles will be produced as a coproduct. Carbon dioxide and fusel oils are other coproducts, all of which enjoy potential market value.

Many factors will determine the percentage yield in small-scale ethanol production. SERI has produced two guidebooks to assist producers in obtaining maximum yields through carefully managed processing and fermentation. *Fermentation Guide for Common Grains* specifies optimum procedures for use with corn, wheat, barley, or milo feedstocks. A companion volume, *Fermentation Guide for Potatoes* identifies specific procedures for the potato-to-ethanol producer. Both publications are now available from the U.S. Government Printing Office (complete ordering information for these and other SERI publications are provided on page 7 of this brochure).

Potential Ethanol Yields of Crops Under Well Managed Conditions

Feedstock	*Maximum Ethanol Yield (Wet)*
Barley	79.2 gal/ton
Cheese Whey	2.43 gal/100 gal
Corn	85 gal/ton
Jerusalem Artichokes	20 gal/ton
Molasses	68-70 gal/ton
Potatoes	22.9 gal/ton
Rice, rough	79.5 gal/ton
Rye	78.8 gal/ton
Sorghum, grain	79.5 gal/ton
Sorghum, sweet	10.5 gal/ton
Sugar Cane	15.2 gal/ton
Wheat	85 gal/ton

Distiller's Dried Grains (DDG). DDG is a coproduct from any grain/alcohol fermentation. This material, containing all of the digestible protein yield of the original feedstock, is a proven livestock feed. Different feedstocks yield different amounts of DDG depending on the protein content of the original crop.

Alcohol as Motor Fuel

The use of ethanol or other alcohols as fuel for internal combustion engines is not a new concept. Henry Ford originally offered automobiles capable of operating on either ethanol or gasoline. With the development of economical petroleum extraction and refining early in this century, gasoline became the more practical fuel and further development of fuel-grade ethanol was shelved. However, alcohol fuels have commonly been used in auto racing because of certain performance characteristics that are superior to gasoline.

Currently, the petroleum "glut" of the early 80's has reduced interest in alternate vehicular fuels. However, because of American experiences with oil shortages within recent years, it is anticipated that the nation will look at alcohol to displace some petroleum-based fuels and chemicals in the future.

Ethanol can be burned directly in modified auto engines, or it can be used as a blend with gasoline — often without engine modification. Many piston-driven engines have been modified to burn straight ethanol after minor adjustments to the carburetor and replacement of certain fuel-line parts. The Solar Energy Research Institute is now studying a novel system that dissociates alcohol into hydrogen and carbon monoxide before combustion. This process has proven to be much more efficient than direct combustion of ethanol or methanol.

Alcohol/Gasoline Blends. Various alcohol/gasoline blends have been evaluated and are in current use today. Blends using more than 25% alcohol are commonly used in Brazil; they require modification to engine parts for proper performance.

Many American retail dealers offer gasohol (a 10% ethanol blend) as acceptable fuel for most spark-ignition engine autos without engine modification. Recently, many gasoline suppliers have begun marketing blends in which a smaller percentage of ethanol is combined with low-lead or unleaded gasolines to

enhance octane rating while maintaining acceptable emissions levels.

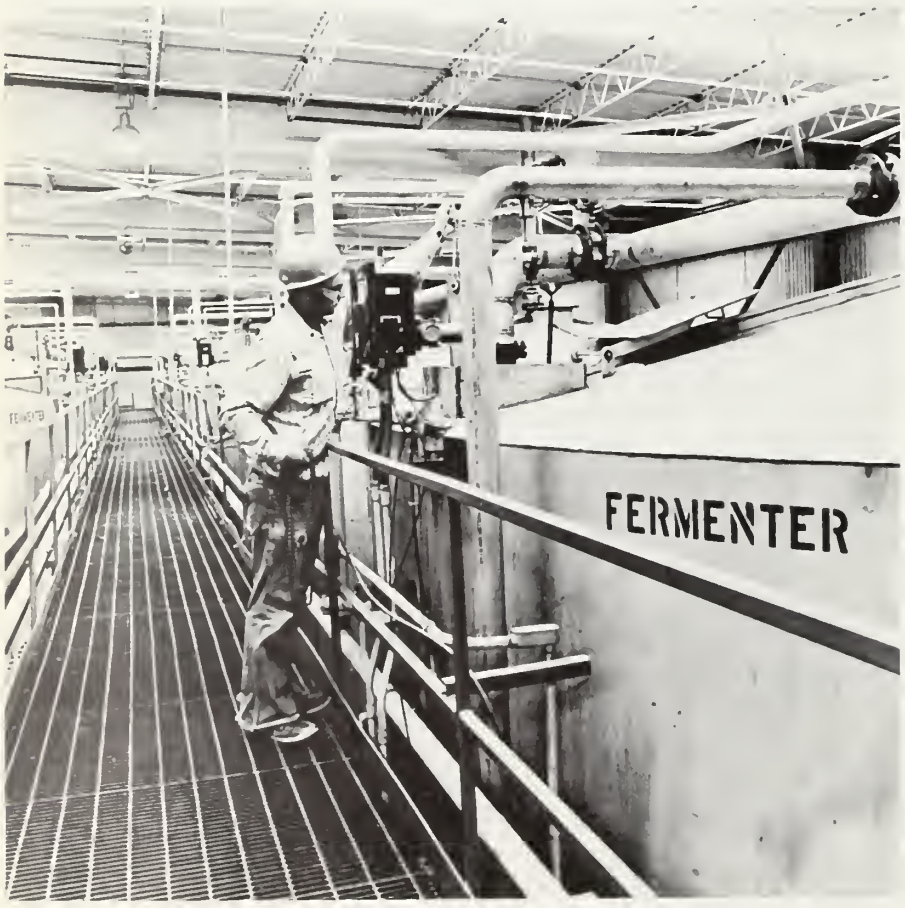
Gasohol, one of these blends, contains 10% anhydrous* ethanol and 90% unleaded gasoline. Existing autos can run on gasohol without engine modifications and with little or no discernible loss of performance.

According to the U.S. Department of Transportation, more than 493 million gallons of gasohol were sold in 32 states during 1980. Figures for 1981 are not yet available as of this printing; however, there are clear indications that sales have dropped in several areas of the country, owing largely to increased availability of gasoline and high gasohol prices. However, many retailers are now marketing ethanol as an enhancer in high-octane unleaded fuels rather than as gasohol, and this may significantly contribute to higher overall sales volumes in the future.

Ethanol as a Diesel Fuel. The minimum practical cetane rating for diesel engines is about 30, while the cetane rating of ethanol is 6.** Because the auto-ignition temperature of ethanol is high when compared to that of a good diesel fuel, it is not practical to use it as a straight fuel in a diesel engine. It is difficult to make stable blends of ethanol and diesel fuel because their liquid characteristics are substantially different.

*Anhydrous means that there is no water present.

**The cetone rating is a comparative ranking of the auto-ignition properties of diesel fuels against a value arbitrarily assigned to cetane, a good diesel fuel.



However, there are methods to permit use of ethanol in diesel engines. They include ethanol carburation at the air intake, dual-fuel injection, on-board mixing, use of cetane boosters blended with ethanol, and spark assist. Keep in mind, however, that use of these devices may void engine warranties.

Performance

Drivers of automobiles using gasohol and other alcohol/gasoline blends have reported varying performance results. These range from increased performance, to no noticeable difference or decreased performance. Because the alcohol molecule contains oxygen, it needs less air to burn. This, together with alcohol's higher octane rating, gives it an advantage as a motor fuel and accounts for favorable performance reports (such as improved mileage per gallon of blend).

However, gallon-for-gallon, ethanol has a significantly lower heat content than gasoline, thereby lessening or canceling some of its inherent advantages as a motor fuel. Some of the major aspects of ethanol/gasoline blend performance are summarized here:

Engine: Engine modifications are not required for 10/90 ethanol/gasoline blends. However, blends using greater percentages of ethanol may require modification of the carburetor and fuel-line parts.

Corrosion: Alcohol may corrode some gas-line component materials. However, there have been no reported cases of corrosion in vehicles using fuel blends containing 10% or less of alcohol.

Vapor Pressure: Alcohol/gasoline blends have been identified

Federal Regulations

The design, construction, and operation of alcohol fuel plants requires attention from federal, state, and local authorities in order to ensure maintenance of the public good. Public Law 96-223 simplified federal regulations for plants that produce fuel alcohol. The Department of the Treasury is now directed to expedite all applications, establish a minimum bond, and generally encourage and promote the production of alcohol for fuel purposes. Production plants must qualify to operate under existing provisions of the law. There are severe penalties for failing to comply with regulations that are currently enforced by the Treasury Department's Bureau of Alcohol, Tobacco, and Firearms (BATF). The Bureau has a fact sheet, *Alcohol Fuel Plants* (publication number 5000.4-1), which outlines these regulations. You can obtain it free of charge from the Public Affairs Office, Bureau of Alcohol, Tobacco, and Firearms, Washington, DC 20226.

with vapor lock in some hot-weather situations. This problem seems more commonly associated with methanol/gasoline blends than with ethanol blends. Some state laws set limits on the allowable vapor pressure of gasoline; because alcohol does increase vapor pressure, the alcohol percentage may need to be limited to achieve compliance.

Fuel Filter: In older cars which have accumulated residue in their fuel systems, the detergent action of alcohol in gasoline may release the residues and clog the fuel filter after the first few tankfuls. Replacement of the fuel filter will solve this problem.

Age of Car: A significant performance difference between old and late model autos with ethanol fuels occurs due to the use of closed-loop feedback systems in the exhaust and fuel-induction systems of recent models. In essence, these new systems use an exhaust oxygen sensor which permits the carburetor to maintain an optimal air/fuel mixture for efficient operation. Such a system is able

to accommodate the differences between unleaded gasoline and alcohol/gasoline blends without the adjustments that may be required on older models.

Mileage: Mileage performance with alcohol blends could be less than that for gasoline, especially in most new cars. For many older cars with less-efficient carburetor systems, use of gasohol and other 10/90 blends may actually improve mileage performance by as much as 5%. This is because older carburetors are often not equipped to burn gasoline at the most favorable fuel/air ratio; however, alcohol blends tend to correct this problem.

Emissions: Studies by the Environmental Protection Agency in 1978 concluded that, when compared with the emissions of gasoline-powered vehicles, alcohol blends:

- Increase evaporative emissions about 50%
- Increase nitrogen oxide emissions about 7%
- Decrease exhaust hydrocarbons about 9%
- Decrease carbon monoxide about 35%

Cars using emission control catalytic converters in good working order usually have acceptable emission performance regardless of which fuel is used; therefore, alcohol blends may not significantly reduce emissions for these vehicles. Vehicles using alcohol fuel blends will emit greater amounts of aldehydes (a combustion by-product), substances that are photochemically reactive. There may be slight adverse environmental effects from this increase; however, this condition is not currently preceived as serious.

High Altitude Performance: Some users of alcohol blends have reported superior performance compared with gasoline operation during high-altitude driving. This is possibly a favorable consequence of alcohol's lesser need for oxygen to burn completely.

More Performance Information: Valuable data on alcohol blend performance has been collected by those organizations using gasohol and other blends as fuels for vehicular fleets. SERI has compiled information from 26 fleet tests in a new publication, *Alcohol-Gasoline Blends as Vehicular Fuels.* This volume is also available from the Government Printing Office (see page 7 for ordering information).

Issues Facing Alcohol Fuel Development

Alcohol fuels that are used for transportation carry a number of advantages, among them:

- They are produced from biomass, a renewable resource.
- Surplus or spoiled crops can be used to produce alcohol fuel, thereby creating a new agricultural market.
- Alcohol fuels can be made from domestic sources, consequently reducing our reliance on imported oil.
- Technical barriers to fermenting alcohol should prove minor since the technology is already proven.

However, concerns have been raised about producing alcohol

fuels to extend or replace petroleum on a national basis. Fears have been voiced that alcohol fuel production will displace food production, forcing up food prices and curtailing surplus crop exports. It is also feared that producing alcohol will drain, rather than supplement conventional fuel reserves. Finally, many fear that ethanol fuel will never be competitive in cost with its conventional counterparts, and that current production incentives will be eliminated. These concerns are discussed here.

Fuel vs. Food Production: Alcohol and food production are *not* mutually exclusive. Based on 1977-78 figures, the U.S. can generate enough *surplus* grain production to provide 8.5 billion gallons of ethanol yearly, equivalent to 8% of total gasoline use at present consumption levels. This level can be achieved *without* disrupting the production of any major food crop.

In fact, most of the food value of the original feedstock is not destroyed by producing alcohol, because DDG (which contains all the protein of the original feedstock) can be produced as a by-product of alcohol fermentation. This protein is reinvested in food production whenever DDG is used as a livestock feed.

Ethanol can also be produced from agricultural feedstocks which do not influence national food production, such as excess, crops, distressed or marginal crops, spoiled vegetable or fruit, and food processing wastes.

Liquid Fuel Gain with Ethanol: It takes energy to convert biomass to ethanol. The energy needed to ferment and distill grain, combined with the energy required to grow and harvest it, can be greater than the energy contained in the ethanol that is produced. However, by designing an efficient ethanol plant that uses minimal fuel in the production process, substantially more liquid fuel will be produced than consumed.

The Price of Ethanol: Due to rapidly fluctuating feedstock prices, it is difficult to predict the market price of ethanol. A 1980 U.S. Department of Agriculture study suggests that, based on corn prices of $2.00 per bushel, ethanol production from corn would cost about $1.75/gallon.

Alcohol fuels are exempt from the 4¢/gallon federal tax on motor fuels. This amounts to an effective subsidy of 40¢/gallon of ethanol for the 10% ethanol component in gasohol. Many states have enacted similar legislation to lower the selling price of ethanol fuel and stimulate consumer demand.

However, even with these subsidies, the price of ethanol blends at the pump is usually higher than the price of competing gasoline fuels. And, most of the state subsidies expire in the mid-1980's. At present there is a significant gap between ethanol and gasoline prices that must be overcome in order for ethanol to become competitive.

Summary

Much has changed in the alcohol fuels market in the last few years. International petroleum prices have slowed their rise, and gasohol sales have dipped. However, ethanol can increase the octane and serve as a valuable extender of petroleum fuels, offering good promise as a new market for spoiled and surplus crops.

For More Information

Facts About Ethanol is an update of the 1979 SERI publication, *Facts About Gasohol.* This new edition briefly presents some of the major factors involved in producing ethanol, along with its use as a fuel extender and octane enhancer.

SERI has published a variety of books that cover these and other ethanol issues in detail. These publications (listed below) may be obtained from: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. When ordering, please make a check or money order payable to the "Superintendent of Documents," and be sure to specify the title and GPO stock number. The prices listed below are subject to change.

- *Fuel From Farms: A Guide to Small-Scale Ethanol Production* provides a comprehensive guide for farm-based ethanol production. Describes fermentation procedures and offers worksheets and guidelines to help the reader evaluate the feasibility of farm-based production. Appendices provide feedstock data, equipment information, manufacturer and

supplier lists, application requirements and regulations enforced by BATF, glossary, bibliography, and more. Price $5.00. GPO Stock #061-000-00372-0.

- *A Guide to Commercial-Scale Ethanol Production and Financing* thoroughly examines the factors involved in setting up a large-scale production operation. Discusses large-scale fermentation technology and offers guidelines and criteria for potential investors and operators. With detailed appendices. Price $8.50. GPO Stock #061-000-00472-6.
- *Fermentation Guide for Common Grains* describes optimum procedures for manufacturing ethanol from corn, wheat, barley, or milo feedstocks. Price $3.00. GPO Stock #061-000-00553-6.
- *Fermentation Guide for Potatoes* outlines recommended procedures when using potatoes as the feedstock. Price $3.00. GPO Stock #061-000-00560-9.
- *Alcohol-Gasoline Blends as Vehicular Fuels* describes the results of 26 fleet tests using alcohol fuels. Price $3.95. GPO Stock #061-000-00558-7.

The Bureau of Alcohol, Tobacco, and firearms has compiled the fact sheet, *Alcohol Fuel Plants*, outlining current regulations. Write: Public Affairs Office, Bureau of Alcohol, Tobacco and Firearms, Washington, D.C. 20226. (BATF Publication #5000.4-1. Copies free.)

Additional copies of *Facts About Ethanol* may be obtained from:

U.S. Department of Agriculture
National Agricultural Library
Room 111
Beltsville, MD 20725
(Free while supply lasts)

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
(Inquire for price)

The following organizations can provide additional information on producing alcohol fuels:

- Land Grant Colleges of the United States
- College & University Energy Information Centers
- State Energy Offices
- State Gasohol Commissions
- Federal/State Cooperative Extension Services
- County Extension Agents

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